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Effects of Chemical Protective Clothing, Exercise, and Diphenhydramine on Cognitive Performance During Sleep Deprivation

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The cognitive performance effects of some stressors experienced in military training and combat were determined in a field experiment. The effects of wearing chemical protective clothing (CPC) at Mission-Oriented Protective Posture Level IV, walking 18 to 24 miles (29–39 km) while carrying a heavy backpack, and taking 50-mg oral doses every 6 hr of diphenhydramine (an antihistamine) were investigated on 72 Marines during a 36-hr sleep deprivation double-blind, placebo-controlled experiment. We administered tests that measured reaction time, spatial ability, memory, and logical reasoning. The results suggest that wearing CPC for an 11-hr period or prolonged engagement in moderate exercise produces general cognitive impairment in sleep-deprived participants. However, after repeated dosing, taking diphenhydramine has little cognitive effect. These results suggest that, if a job is near the limit of a person's cognitive abilities, performance may suffer if the person is sleep deprived and required to wear CPC or engage in prolonged, moderate exercise.

Military personnel are faced with stressors that may compromise their ability to perform their mission. Apart from the emotional intensity of combat, other stressors may adversely affect fighting ability. Combat often requires physical exertion and sometimes requires wearing chemical protective clothing (CPC). Furthermore,

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soldiers may take medication, such as a chemical warfare prophylactic or antidote, or over-the-counter drugs. Additional stress may result from insufficient sleep and subsequent fatigue. The effects of these stressors on soldiers may be cumulative and synergistic. The effects of three specific stressors—wearing CPC, exercising, and taking diphenhydramine—are reviewed.

Military CPC, designed to protect the wearer from agents used in biological or chemical warfare, is impermeable and allows minimal evaporation of the wearer's perspiration. Depending on the duration worn, activity level, and environmental circumstances, perspiration may pool in face mask, boots, and gloves. CPC ensembles are also cumbersome, requiring soldiers to expend greater energy to move. Even with soldiers experienced in wearing CPC, this clothing may produce panic, confusion, dyspnea, and fear in 20% of them; some of these reactions may occur in the first 10 min of an exercise or immediately after putting on the mask (Brooks, Xenakis, Ebner, & Balson, 1983). Carter and Cammermeyer (1985) found that the most frequent complaints of those wearing CPC were rapid breathing, shortness of breath, and loss of peripheral vision, which were experienced by 49% of the participants. Simply being confined in the suit may produce panic in individuals susceptible to claustrophobia. Apart from the problem of encapsulation, wearing the gas mask respirator increases breathing effort and can lead to physiological and psychological problems for some people. Gas masks and other filter respirators alter pulmonary function (Kelly et al., 1987; Raven, Dodson, & Davis, 1979), decrease endurance (Craig, Blevins, & Cummings, 1970; Stemler & Craig, 1977), and produce adverse psychological consequences, such as panic (Brooks et al., 1983; Carter & Cammermeyer, 1985; Morgan, 1983; Morgan & Raven, 1985).

Previous research on the effects of wearing a protective mask, without other protective clothing, has shown cognitive decrements. Spioch, Kobza, and Rump (1962) showed an increase in reaction time on the Bourdan test, which is a letter, number, and word cancellation test. On comparable participants, wearing the M17A2 facial mask resulted in a decrement in Simple Reaction Time performance and a decrement in the number of responses in a tapping test but resulted in no difference in Wilkinson's Four-Choice reaction time test or Baddeley's Logical Reasoning test (Kelly, Ryman, et al., 1988). This suggests that the mask may be responsible for some of the decrements in cognitive performance when participants wear CPC. These decrements could result from the restricted visual field and from the psychological and physiological effects of wearing a respirator.

Previous research on the effects of wearing CPC on cognitive performance has produced mixed results. The majority of the research found evidence of a cognitive performance decrement (Englund et al., 1987; Englund, Sucec, Yeager, Ryman, & Sinclair, 1988; Kelly, Englund, Ryman, Yeager, & Sucec, 1988; Kobrick & Sleeper, 1986; Rauch, Witt, Banderet, Tauson, & Golden, 1986), which has been attributed to the physical effects of wearing CPC—chiefly the limited vision produced by wearing the mask and the clumsiness produced by wearing the gloves. However, some researchers have not found any cognitive performance decrement (Arad et al., 1992; Hamilton, Simmons, & Kimball, 1983). Fine (1988) put individuals wearing CPC in a hot, humid room and found no cognitive decrement in those who completed the experiment. One report showed that wearing CPC produced an improvement in performance (Hamilton & Zapata, 1983).

The typical finding in the research on the second stressor, exercise, is that it improves cognitive performance (Tomporowski & Ellis, 1986). The few experiments that have addressed strenuous exercise, similar to the level experienced in combat, found facilitation on spatial tests (Lybrand, Andrews, & Ross, 1954), facilitation on vigilance (Gliner, Matsen-Twisdale, Horvath, & Maron, 1979), or slight facilitation on memory, which was not statistically significant (Tomporowski, Ellis, & Stephens, 1987).

The third stressor, diphenhydramine, is an H1-histamine blocker administered for the relief of allergy symptoms. The two most commonly reported side effects are drowsiness (Rickels et al., 1983; Roth, Roehrs, Koshorek, Sicklesteel, & Zorick, 1987) and mental impairment both on cognitive tests (Baugh & Calvert, 1977; Linnoila, 1973; Rice & Snyder, 1993) and on a driving simulator (Gengo, Gabos, & Mechtler, 1990). The effects of diphenhydramine were of interest because of its widespread use and because it was unclear how its side effects of sedation and cognitive impairment would interact with the cognitive changes due to sleep deprivation, exercise, and wearing CPC.

The majority of the research on this drug investigated the effects of a single oral dose of the drug, rather than the effect of repeated doses. Single doses lead to drowsiness and cognitive impairment. About half of patients experienced drowsiness (Gilman, Rall, Nies, & Taylor, 1990), and cognitive impairment was not always found at the standard dosage of 50 mg (Pishkin, Sengel, Lovallo, & Shurley, 1983) or even at twice the standard dosage (Schrot, Thomas, & Van Orden, 1990). When performance decrements are found, they are for some measures on some tests and for a limited duration. At the standard dosage, plasma concentration peaks 2 hr postingestion, stays at that level for another 2 hr (Babe & Serafin, 1996), and has an estimated half-life of 8.5 hr (Benet, Oie, & Schwartz, 1996). Problems with mental impairment typically are maximal 1 to 4 hr postingestion and can last for 5.1 to 6.6 hr (Licko, Thompson, & Barnett, 1986).

Research of the effect of repeated dosing has found that tolerance to the side effects of diphenhydramine develops very quickly (Gilman et al., 1990). The sole study that used repeated dosing found the performance decrement for the 1st day of dosing did not occur in subsequent testing on the 3rd day of dosing (Schweitzer, Muehlbach, & Walsh, 1994). The participants were not tested on the 2nd day of dosing, however, so the rate of achieving tolerance cannot be determined from this study.

The field experiment reported here investigated the cognitive effects of wearing CPC, engaging in prolonged, periodic physical exercise, and taking diphenhydramine in participants who were sleep deprived for 36 hr. The purpose of this study was to determine the level and nature and, when possible, the source of cognitive performance decrements produced by combat-related stressors. This information should facilitate prediction of the operational consequences of these stressors. Thirteen cognitive tests, which assessed reaction time, spatial ability, memory, and reasoning, were administered. The administration of multiple tests within each cognitive ability allowed examination of the pattern of results across tests and provided more generality than would be obtained with the use of fewer tests. This was especially important because the sensitivity of these tests to stressors was unknown (cf. D. Williams, 1995), and some of the tests may be insensitive to stressor-induced cognitive decrement. The use of a variety of tests was especially important in determining the source of the cognitive performance decrement caused by wearing CPC. Depending on the visual angle of information displayed to the participants wearing a gas mask and the response requirements, limitations in vision and dexterity produced by wearing this clothing would be expected to differentially affect performance on cognitive tests having different characteristics. Using several tests allowed estimation of the size of various sources of cognitive performance decrements.

METHOD

Participants

Ninety-six male Marines from the First Marine Division, Camp Pendleton, California, voluntarily participated in the experiment. They ranged in age from 18 to 38 years, and most of the participants had experience wearing CPC. Each participant was studied over a 2-week interval. During the 1st week, they spent 2 days in the laboratory, and during the 2nd week, they spent 4 days in the field. Due to difficulties with the initial data collection, the data from the first 24 participants were not used in the analyses. The results reported here were obtained from the remaining 72 participants.

Materials

Thirteen cognitive tests from the computerized Naval Health Research Center Performance Assessment Battery (PAB) were administered periodically (D. Williams, Englund, Sucec, & Overson, 1995). This PAB is very similar to the widely used Walter Reed PAB (Thorne, Genser, Sing, & Hegge, 1985). The tests chosen from this battery were (a) reaction time tests (Choice Reaction Time, Simple Reaction Time, Tapping, and Wilkinson's Four-Choice), (b) spatial tests (Manikin, Matrix-2, and Time Wall), (c) memory tests (Digit Recall, Single Digit Substitution, and Six-Letter Search), and (d) reasoning tests (Encode/Decode, Logical Reasoning, and Serial Addition/Subtraction). These tests were presented on Zenith model ZVC-1-AA desktop computers, based on the original IBM PC XT architecture.

For most of the tests, the computer presented a stimulus on a computer monitor, and the soldier indicated his response by pressing a key on a computer keyboard. An exception was Tapping, in which a participant alternately pressed two keys with the index finger of his dominant hand. If the participant pressed a nonresponse key when a response was expected or pressed any key when a response was not expected, a warning tone sounded. During practice trials, this tone also sounded after an incorrect response. During both practice and data collection trials, a summary of the participant's performance was presented at the end of each test.

Each participant used his own CPC issued by the Marine Corps, including a prescription lens insert if he required it. Prospective participants who needed these lenses but did not bring them were dropped from the experiment. The CPC was an Overgarment-84 (OG84) suit and either an M17A1 or M17A2 mask. The CPC was worn at the Mission-Oriented Protective Posture Level IV, which provides the maximum protection. The control group for CPC wore the standard camouflage utility uniforms issued by the Marine Corps. Participants wearing CPC and assigned to the exercise condition exchanged the mask issued by the Marine Corps for an M17A2 mask before engaging in exercise, allowing collection of expired air.

Design

The cognitive tests were divided into three batteries. Battery 1 consisted of Single Digit Substitution, Logical Reasoning, Manikin, Six-Letter Search, and Time Wall. Battery 2 consisted of Encode/Decode, Digit Recall, Choice Reaction Time, and Tapping. Battery 3 consisted of Serial Addition/Subtraction, Wilkinson Four-Choice, Matrix-2, and Simple Reaction Time. The tests were administered in the listed order within each battery.

The experiment had both between-subjects and within-subject factors. There were two levels each of exercise (walking with a backpack or sitting), drug (diphenhydramine or placebo), and clothing (CPC or utility work uniform), which were between-subjects factors. As seen in the testing schedule in Table 1, the participants were administered the 13 tests from the three test batteries on four occasions. This within-subject factor was labeled the *block* variable. The design of the entire experiment was a 2 (exercise) × 2 (drug) × 2 (clothing) × 4 (block) factorial. Because of the discomfort of wearing CPC, the participants who wore CPC did so only for the last 11 hr of the experiment, donning the CPC partway through the third testing block. Thus, the experimental design is not a complete factorial. The data reported here are from the final block of trials, making the design a 2 (exercise) × 2 (drug) × 2 (clothing) complete factorial. All data reported are from mildly sleep-deprived participants because the participants had already missed one night of sleep by the beginning of the testing presented here.

TABLE 1
Testing Schedule

Day	Time	Session	Battery	Block
Tuesday	0700	1	1	
	0812	2	1	1
	0924	3	2	1
	1036	4	2	1
	1148	5	3	1
	1300	Break		
	1400	6	3	1
	1512	7	1	2
	1624	8	1	2
	1736	9	2	2
	1848	10	2	2
	2000	Break		
	2100	11	3	2
	2212	12	3	2
	2324	13	1	3
Wednesday	0036	14	1	3
	0148	15	2	3
	0300	Long break		
	0700	16	2	3[a]
	0812	17	3	3
	0924	18	3	3
	1036	19	1	4[b]
	1148	20	1	4[b]
	1300	Break		
	1400	21	2	4[b]
	1512	22	2	4[b]
	1624	23	3	4[b]
	1736	24	3	4[b]
	1848	Done		

[a]Chemical protective clothing donned. [b]Data analyzed for effects of chemical protective clothing.

Procedure

Participants were run in groups of 24, and they were randomly assigned to each of the eight conditions. The week prior to the field study, the participants were instructed how to do the cognitive tests and completed each test twice in a laboratory setting. The field study was conducted outdoors and in tents during the summer at Camp Del Mar, Camp Pendleton, California, about a quarter of a mile from the ocean. The temperature during the day was approximately 75 °F (24 °C) and dropped to approximately 65 °F (18 °C) at night.

On the 1st day of the experiment, participants awakened at 0500 hr and began the experiment at 0700 hr. During each 72-min testing interval, the exercisers walked 1 mile (1.61 km) around an outdoor quarter-mile (0.40 km) dirt track, carrying a military backpack that weighed 50% of their body weight. They were paced to maintain a rate of 5.56 km/h for 20 min. During odd-numbered testing intervals, the exercisers completed questionnaires; on even-numbered intervals, they took computerized tests. On odd-numbered testing intervals, the nonexercisers both completed questionnaires and took the computerized tests. During even-numbered intervals, they were assigned reading from military training manuals. The questionnaires and computerized tests were completed and assigned reading was done in tents adjacent to the track. Before taking the computerized tests, physiological measurements such as heart rate, blood pressure, and grip strength, were made; these data are not included in this report.

The participants were given scheduled breaks, including a 1-hr meal break at 1300 hr and 2000 hr. At 0300 hr, the participants were given a 4-hr rest break during which they were monitored to ensure that they did not sleep.

Administration of the diphenhydramine was double blinded and placebo controlled. Participants in the drug condition received 50 mg every 6 hr, the standard adult dosage. The first dose was given before the first testing interval, followed by 6 more doses during the experiment, for a total of 7 doses. The control participants received placebo capsules at each dosing interval.

Participants who wore CPC kept the entire ensemble on except during meal breaks when they removed the hood and the gloves or when they used the restroom. The longest interval they wore the entire clothing ensemble was 5 hr.

Because the participants who wore CPC were not physically able to smoke cigarettes, to ensure comparability of the participants wearing CPC and utility clothing and to simulate the circumstances of military maneuvers, the participants in all conditions were only allowed to smoke during the long break. Few participants smoked during this break, although 36% of the participants reported that they were smokers. Of the participants who completed the experiment, the number of smokers was similar in all conditions.

All 36 participants in the nonexercise group and 26 participants in the exercise group completed the experiment. One participant quit the experiment, and a few became too fatigued to continue. The rest were dropped for medical reasons, mostly due to severe foot blisters. Data for participants who did not complete the experiment were excluded from the analysis.

RESULTS AND DISCUSSION

Dependent Measures and Analyses

A sensitivity analysis was done across four stressors (clothing, drug, exercise, and block), and a single set of four dependent measures was chosen to analyze the effects of the stressors in the entire data set (D. Williams, 1995). The selected measures were maximally sensitive, had minimal overlap with other measures, completely characterized the participants' cognitive performance, and had potential operational relevance. When there was no principled reason to choose one measure over another similar one, the measure used by other researchers was chosen to facilitate comparison of results among studies. This resulted in the selection of two nontraditional measures, Percent Lapses and Correct Per Minute, and two traditional measures, Correct Response Reaction Time and Percent Correct.

Lapses, which are excessively long responses, were first observed in the performance of sleep-deprived participants by Patrick and Gilbert in 1896, and they were confirmed in subsequent research (Bills, 1931, 1958; Bjener, 1949; Warren & Clarke, 1937; H. L. Williams, Lubin, & Goodnow, 1959). The cutoff point used to mark the division between normal responses and excessively long responses was twice the group median. Responses faster than this cutoff were considered normal responses; responses taking longer than this cutoff were considered lapses. Percent Lapses was calculated by dividing the number of lapses by the total number of items presented to which the participant responded. This measure may index the percentage of times the participants lost attentional focus, and it will be referred to as *lapsing*.

Correct Per Minute is the number of correct responses divided by the total response time, and it was computed for each participant. The denominator is the sum of the participant's reaction times, including lapses, and it represents the time he was actually doing the task. It is not the *total* time on task because that measure would include the period of time while the participant waited for the stimulus to be presented. Correct Per Minute is the number of correct reactions per minute of response time and could be called Correct Per Working Minute. This measure combines accuracy and speed data into a single measure that indexes the overall effectiveness of the participant. It has been called "throughput" (Thorne, Genser, Sing, & Hegge, 1983) and an efficiency index (Glenn & Parsons, 1990). Subsequently, it will be referred to as *rate*.

Correct Response Reaction Time is the reaction time for all correct responses, excluding lapses. This is the average amount of time it took participants to answer questions when they performed accurately and responded within a reasonable time and will be referred to as *reaction time*.

Percent Correct is the number correct divided by the number of items presented to which the participants responded, including lapses. Subsequently, it will be referred to as *accuracy*.

These four measures were separately analyzed for each cognitive test using an analysis of variance (Hays, 1973) for a 2 (clothing) × 2 (exercise) × 2 (drug) between-subjects design. The means, standard deviations, and number of participants are tabled for each dependent variable. Test results for the clothing factor are presented in Table 2, activity results are presented in Table 3, and diphenhydramine results are presented in Table 4.

This information was used to calculate effect sizes, also called the *d* statistic (Cohen, 1988), using the following formula: (Experimental Mean – Control Mean)/Pooled Standard Deviation. The *d* statistic is equivalent to the more familiar *z* score. Based on surveys of the social sciences literature, Cohen suggested that *d* statistic effect sizes of 0.2 be considered small, 0.5 be considered medium, and 0.8 be considered large. The *d* statistic effect sizes for each test and dependent measure are presented in Tables 5 through 7. Proponents of meta-analysis challenge the importance of hypothesis testing, and they argue that the *d* statistic reveals a much more consistent picture than that depicted by hypothesis testing (cf. Glass, McGaw, & Smith, 1981; Hunter, Schmidt, & Jackson, 1982; Loftus, 1991, 1993; Schmidt, 1992).

Baseline Data

Participants were randomly assigned to experimental groups with no attempt to match them on any variables. To determine the comparability of the groups, data collected during the training sessions preceding the experimental data collection were analyzed to determine main effects indicating group differences. No differences were found for clothing, three differences were found for activity, and one difference was found for drug.

The activity group differences were in accuracy for Choice Reaction Time, $F(1, 55) = 4.12$, $p < .047$, in which exercise group members were less accurate, and for Serial Addition/Subtraction, $F(1, 53) = 5.75$, $p < .020$, in which exercise group members were more accurate. There was also an activity group difference in rate for Single Digit Substitution, $F(1, 55) = 5.07$, $p < .028$, in which exercise group members worked at a higher rate. For the drug factor, there was a difference in Correct Per Minute for Matrix-2, $F(1, 54) = 6.75$, $p < .012$, in which drug group participants had a lower rate.

The experimental results for comparisons in which the groups differed at baseline are presented, but they are designated as confounded. These results were not included in averaged estimations of effect size.

Discarding Data

Summary data for each participant were examined to determine whether the participant was attempting to do the task or simply answering as quickly as possible. When the sum of each participant's reaction time for all responses (correct and incorrect, lapse and nonlapse) were less than 20% of the average reaction time, and accuracy was close to chance, all of the participant's data were discarded. Participants were dropped from only 3 of the 13 tasks: 10 from Logical Reasoning, 5 from Six-Letter Search, and 2 from Manikin.

TABLE 2
Cognitive Test Results for Clothing Factor

	Correct Response Reaction Time[a]		Percent Lapses		Percent Correct		Correct Per Minute[b]	
Test	*CPC*	*Utility*	*CPC*	*Utility*	*CPC*	*Utility*	*CPC*	*Utility*
Reaction time tests								
Choice Reaction Time								
M	1.22	1.10*	5	6	87	96*	40.57	49.11**
SD	0.20	0.17	5	7	20	11	10.80	12.00
n	29	31	29	31	29	31	29	31
Simple Reaction Time[c]								
M	0.44	0.41[d]	29	18*	—	—	91.78	117.71*[d]
SD	0.08	0.07	22	17	—	—	49.10	46.60
n	23	32	23	32	—	—	23	32
Tapping								
M	0.22	0.21[d]	4	3	91	95**[d]	221.95	253.01*[d]
SD	0.03	0.04	4	3	6	6	48.20	63.80
n	29	31	29	31	29	31	29	31
Wilkinson Four-Choice								
M	0.59	0.57[d]	15	4***	70	84**	59.90	87.01***
SD	0.10	0.12	15	5	20	20	20.90	16.80
n	26	33	26	33	26	33	26	33
Spatial tests								
Manikin								
M	1.97	1.73[e]	13	10	90	94[d,e]	25.07	34.21*[d,e]
SD	0.50	0.47	14	14	14	9	9.50	20.10
n	28	31	28	31	28	31	28	31
Matrix-2								
M	1.44	1.16*	25	14**	55	56[d]	15.69	26.54***
SD	0.45	0.40	17	21	11	12	10.90	16.10
n	28	33	28	33	28	33	28	33

Time Wall[f]								
M	0.02	0.01	—	—	—	—	—	—
SD	0.04	0.01	—	—	—	—	—	—
n	28	33	—	—	—	—	—	—
Memory tests								
Digit Recall								
M	3.87	3.80	14	12	39	42[d]	5.32	5.49[d]
SD	1.50	1.30	17	20	22	17	3.10	2.76
n	28	30	29	31	29	31	29	31
Single Digit Substitution								
M	3.14	2.78*	18	12	50	58	7.83	10.54*
SD	0.69	0.51	17	11	20	22	3.40	4.90
n	28	33	28	33	28	33	28	33
Six-Letter Search								
M	4.81	4.18	11	7	76	85*	10.20	16.29*
SD	1.90	2.10	13	11	17	17	5.30	11.70
n	26	30	26	30	26	30	26	30
Reasoning tests								
Serial Addition/Subtraction								
M	1.52	1.34*	20	12**	72	85*	20.67	33.44***
SD	0.28	0.33	14	10	25	21	10.60	14.50
n	28	33	28	33	28	33	28	33
Encode/Decode								
M	26.17	22.87*	4	5	71	83	1.71	2.32*
SD	4.30	5.40	10	11	34	24	0.89	1.09
n	26	31	29	32	29	32	29	32
Logical Reasoning								
M	3.56	3.61[d]	16	15	74	78[d]	11.87	11.54[d]
SD	1.30	0.89	13	19	19	20	6.90	4.37
n	25	29	25	29	25	29	25	29

Note. CPC = chemical protective clothing.
[a]In sec. [b]Correct Per Minute is (No. Correct)/(Total Reaction Time). [c]Simple Reaction Time tabled value is Response Reaction Time. [d]Possible confounding due to the gloves. [e]Possible confounding due to the mask. [f]Time Wall tabled value is the absolute value of (Estimated Arrival Time – Actual Arrival Time)/(Total Fall Time).
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

TABLE 3
Cognitive Test Results for Activity Factor

Test	Correct Response Reaction Time[a]		Percent Lapses		Percent Correct		Correct Per Minute[b]	
	Exercise	*Sedentary*	*Exercise*	*Sedentary*	*Exercise*	*Sedentary*	*Exercise*	*Sedentary*
Reaction time tests								
Choice Reaction Time								
M	1.15	1.17	6	5	91	92[c]	43.96	45.76
SD	0.16	0.21	6	6	19	15	12	12.40
n	26	34	26	34	26	34	26	34
Simple Reaction Time[d]								
M	0.44	0.40*	29	18*	—	—	90	118.99
SD	0.07	0.07	17	21	—	—	38	52.80
n	23	32	23	32	—	—	23	32
Tapping								
M	0.21	0.22	5	3**	91	95**	228.60	245.18
SD	0.03	0.04	4	2	8	5	69.40	48.40
n	26	34	26	34	26	34	26	34
Wilkinson Four-Choice								
M	0.58	0.58	9	9	77	78	73.32	76.45
SD	0.10	0.12	9	13	20	22	24.90	21.60
n	26	33	26	33	26	33	26	33
Spatial tests								
Manikin								
M	1.80	1.89	11	12	93	92	27.19	31.98
SD	0.30	0.61	12	16	9	14	9.20	20.30
n	26	33	26	33	26	33	26	33
Matrix-2								
M	1.32	1.27	27	12***	54	57	18.62	23.89
SD	0.43	0.46	24	13	10	13	16.40	13.30
n	27	34	27	34	27	34	27	34

Time Wall[e]								
M	0.02	0.02	—	—	—	—	—	—
SD	0.02	0.03	—	—	—	—	—	—
n	26	35	—	—	—	—	—	—
Memory tests								
Digit Recall								
M	3.65	3.96	19	8*	36	44	4.64	6.00
SD	1.50	1.30	25	9	19	20	2.50	3.10
n	24	34	26	34	26	34	26	34
Single Digit Substitution								
M	2.76	3.09	13	16	53	56	9.37	9.25[c]
SD	0.62	0.58	16	12	19	23	4.10	4.80
n	26	35	26	35	26	35	26	35
Six-Letter Search								
M	4.30	4.61	8	9	78	83	14.20	12.87
SD	2.00	2.10	12	12	17	18	11.30	8.40
n	25	31	25	31	25	31	25	31
Reasoning tests								
Serial Addition/Subtraction								
M	1.38	1.46	17	14	76	81[c]	25.44	29.28
SD	0.26	0.36	14	12	26	22	14.20	14.30
n	27	34	27	34	27	34	27	34
Encode/Decode								
M	24.07	24.58	7	2*	75	80	1.90	2.13
SD	4.60	5.50	13	6	33	27	1.10	0.99
n	23	34	26	35	26	35	26	35
Logical Reasoning								
M	3.63	3.55	21	11*	76	77	9.84	12.97*
SD	0.98	1.20	17	15	17	22	3.90	6.30
n	22	32	22	32	22	32	22	32

[a]In sec. [b]Correct Per Minute is (No. Correct)/(Total Reaction Time). [c]The activity groups differed at baseline on this measure. [d]Simple Reaction Time tabled value is Response Reaction Time. [e]Time Wall tabled value is the absolute value of (Estimated Arrival Time – Actual Arrival Time)/(Total Fall Time).

$*p < .05$. $**p < .01$. $***p < .001$.

TABLE 4
Cognitive Test Results for Drug Factor

	Reaction Time[a]		Percent Lapses		Percent Correct		Correct Per Minute[b]	
Test	*Drug*	*Placebo*	*Drug*	*Placebo*	*Drug*	*Placebo*	*Drug*	*Placebo*
Reaction time tests								
Choice Reaction Time								
M	1.16	1.16	7	4	89	94	44.47	45.52
SD	0.22	0.15	6	5	20	12	11.70	12.80
n	31	29	31	29	31	29	31	29
Simple Reaction Time[c]								
M	0.42	0.42	24	21	—	—	106.21	107.50
SD	0.09	0.07	21	18	—	—	55.30	42.50
n	28	27	28	27	—	—	28	27
Tapping								
M	0.22	0.21	4	3	92	94	227.64	249.06
SD	0.03	0.04	3	3	7	5	54.90	61.10
n	31	29	31	29	31	29	31	29
Wilkinson Four-Choice								
M	0.57	0.58	10	7	78	78	73.73	76.56
SD	0.10	0.10	14	9	23	19	23.70	22.50
n	31	28	31	28	31	28	31	28
Spatial tests								
Matrix-2								
M	1.31	1.26	22	16	55	56	17.98	25.51*[d]
SD	0.43	0.47	18	21	12	11	11.50	17.20
n	32	29	32	29	32	29	32	29
Manikin								
M	1.80	1.89	11	13	91	94	30.07	29.66
SD	0.47	0.53	14	15	15	9	14.60	18.60
n	31	28	31	28	31	28	31	28

Time Wall[e]								
M	0.02	0.01	—	—	—	—	—	—
SD	0.03	0.01	—	—	—	—	—	—
n	32	29	—	—	—	—	—	—
Memory tests								
Digit Recall								
M	3.66	4.03	12	14	38	42	5.20	5.64
SD	1.30	1.40	14	22	18	21	2.80	3.10
n	31	27	31	29	31	29	31	29
Single Digit Substitution								
M	2.90	2.99	13	16	54	55	9.17	9.44
SD	0.60	0.70	12	16	24	18	4.70	4.30
n	32	29	32	29	32	29	32	29
Six-Letter Search								
M	4.58	4.34	9	9	82	79	13.00	14.00
SD	2.00	2.10	12	12	16	19	9.10	10.50
n	30	26	30	26	30	26	30	26
Reasoning tests								
Serial Addition/Subtraction								
M	1.40	1.46	15	16	77	81	27.91	27.20
SD	0.40	0.30	13	14	27	20	16.40	11.70
n	32	29	32	29	32	29	32	29
Encode/Decode								
M	23.20	25.70	2	7	81	74	2.28	1.76
SD	5.20	4.90	5	13	30	30	1.10	0.90
n	30	27	32	29	32	29	32	29
Logical Reasoning								
M	3.64	3.53	16	15	76	76	10.94	12.45
SD	1.00	1.30	18	14	21	19	4.20	6.70
n	27	27	27	27	27	27	27	27

[a]In sec. [b]Correct Per Minute is (No. Correct)/(Total Reaction Time). [c]Simple Reaction Time tabled value is Response Reaction Time. [d]The drug groups differed at baseline on this measure. [e]Time Wall tabled value is the absolute value of (Estimated Arrival Time – Actual Arrival Time)/(Total Fall Time).

$^{*}p < .05$.

TABLE 5
Effect Sizes for Clothing Factor

Test	*Correct Response Reaction Time*	*Percent Lapses*	*Percent Correct*	*Correct Per Minute*
Reaction time tests				
Choice Reaction Time	0.65*	−0.16	−0.56*	−0.74**
Simple Reaction Time	0.40[a]	0.55*	—	−0.54
Tapping	0.28[a]	0.28	−0.67**[a]	−0.61*[a]
Wilkinson Four-Choice	0.27[a]	0.98***	−0.70**	−1.45***
M	0.65	0.41	−0.63	−0.91
Spatial tests				
Matrix-2	0.66*	0.58**	−0.09[a]	−0.78***
Manikin	0.56*[b]	0.21	−0.34[a,b]	−0.58*[a,b]
M	0.66	0.40	—	−0.78
Memory tests				
Digit Recall	0.05	0.11	−0.15[a]	0.00[a]
Single-Digit Substitution	0.59*	0.42	−0.38	−0.57*
Six-Letter Search	0.31	0.33	−0.53*	−0.67*
M	0.32	0.29	−0.46	−0.62
Reasoning tests				
Serial Addition/Subtraction	0.59*	0.66**	−0.56*	−1.04***
Encode/Decode	0.68*	−0.10	−0.41	−0.63*
Logical Reasoning	0.04[a]	−0.06	−0.21[a]	0.06[a]
M	0.64	0.17	−0.39	−0.84
Average (overall – unconfounded)	0.50	0.32	−0.52	−0.80
Average (significant only – unconfounded)	0.63	0.69	−0.61	−0.84

Note. Tabled values are the means for (Chemical Protective Clothing – Utility)/*SD*.
[a]Possible confounding due to the gloves. [b]Possible confounding due to the mask.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Reaction Time Tests

Choice Reaction Time. For Correct Response Reaction Time, Percent Correct, and Correct Per Minute, there was an effect of clothing, $F(1, 52) = 4.92$, $p < .031$; $F(1, 52) = 4.99$, $p < .03$; and $F(1, 52) = 8.52$, $p < .005$, respectively. Participants wearing CPC had longer reaction times, were less accurate, and worked at a slower rate, with effect sizes of 0.65, −0.56, and −0.74, respectively.

Simple Reaction Time. Because this test has no accuracy measure, Response Reaction Time was used instead of Correct Response Reaction Time. For Response Reaction Time, there was an effect of exercise, $F(1, 47) = 4.43$, $p < .04$. For Percent Lapses, there was an effect of clothing, $F(1, 47) = 6.28$, $p < .016$, and of exercise, $F(1, 47) = 5.90$, $p < .019$. Participants wearing CPC had more lapses, with effect sizes of 0.55, and exercise participants had longer reaction times and lapsed more frequently, with effect sizes of 0.57 and 0.58, respectively.

Tapping. In this test, accuracy was determined by comparing the percentage of successful alternations with the number of failures to alternate. For Percent Lapses, there was an effect of exercise, $F(1, 52) = 9.20$, $p < .004$. For Percent Correct, there was an effect of clothing, $F(1, 52) = 7.50$, $p < .008$, and of exercise, $F(1, 52) = 9.76$, $p < .003$. For Correct Per Minute, there was an effect of clothing, $F(1, 52) = 5.51$, $p < .023$. Participants wearing CPC were less accurate and worked at a slower rate, with effect sizes of –0.67 and –0.61, respectively, and exercise participants had more lapses and were less accurate, with effect sizes of 0.63 and –0.60, respectively.

TABLE 6
Effect Sizes for Activity Factor

Test	*Correct Response Reaction Time*	*Percent Lapses*	*Percent Correct*	*Correct Per Minute*
Reaction time tests				
Choice Reaction Time	–0.11	0.17	–0.06[a]	–0.15
Simple Reaction Time	0.57*	0.58*	—	–0.63
Tapping	–0.28	0.63**	–0.60**	–0.17
Wilkinson Four-Choice	0.00	0.00	–0.05	–0.13
M	0.05	0.35	–0.33	–0.27
Spatial tests				
Matrix-2	0.11	0.78***	–0.26	–0.37
Manikin	–0.19	–0.07	0.08	–0.30
M	–0.04	0.36	–0.09	–0.34
Memory tests				
Digit Recall	–0.22	0.59*	–0.41	–0.44
Single Digit Substitution	–0.55	–0.21	–0.14	0.13[a]
Six-Letter Search	–0.15	–0.08	–0.29	–0.13
M	–0.31	0.10	–0.28	–0.29
Reasoning tests				
Serial Addition/Subtraction	–0.25	0.23	–0.21[a]	–0.29
Encode/Decode	–0.10	0.49*	–0.17	–0.50
Logical Reasoning	–0.07	0.62*	–0.05	–0.60*
M	–0.14	0.45	–0.11	–0.46
Average (overall – unconfounded)	–0.10	0.31	–0.21	–0.34
Average (significant only – unconfounded)	0.57	0.62	–0.60	–0.60

Note. Tabled values are the means for (Exercise – Sedentary)/*SD*.
[a]The activity groups differed at the baseline on this measure.
*$p < .05$. **$p < .01$. ***$p < .001$.

TABLE 7
Effect Sizes for Drug Factor

Test	*Correct Response Reaction Time*	*Percent Lapses*	*Percent Correct*	*Correct Per Minute*
Reaction time tests				
Choice Reaction Time	0.00	0.54	−0.30	−0.10
Simple Reaction Time	0.00	0.15	—	0.03
Tapping	0.28	0.33	−0.33	−0.27
Wilkinson Four-Choice	−0.10	0.25	0.00	−0.13
M	0.05	0.32	−0.21	−0.12
Spatial tests				
Matrix-2	0.11	0.31	−0.09	−0.53*[a]
Manikin	−0.18	−0.14	−0.24	0.02
M	−0.04	0.09	−0.17	0.02
Memory tests				
Digit Recall	−0.27	−0.11	−0.20	0.00
Single Digit Substitution	−0.14	−0.22	−0.05	−0.13
Six-Letter Search	0.12	0.00	0.17	−0.10
M	−0.10	−0.11	−0.03	−0.08
Reasoning tests				
Serial Addition/Subtraction	−0.19	−0.07	−0.17	0.09
Encode/Decode	−0.50	−0.51	0.23	0.63
Logical Reasoning	−0.10	0.06	0.00	−0.27
M	−0.26	−0.17	0.02	0.15
Average (overall – unconfounded)	−0.08	0.05	−0.09	−0.02
Average (significant only – unconfounded)	—	—	—	—

Note. Tabled values are the means for (Diphenhydramine – Placebo)/*SD*.
[a]The drug groups differed at baseline on this measure.
*$p < .05$.

Wilkinson's Four-Choice. For Correct Response Reaction Time, there was an interaction of clothing, exercise, and drug, $F(1, 51) = 4.11$, $p < .048$. For Percent Lapses, there was an effect of clothing, $F(1, 51) = 17.90$, $p < .0001$, and an interaction of clothing, exercise, and drug, $F(1, 51) = 6.32$, $p < .015$. For Percent Correct, there was an effect of clothing, $F(1, 51) = 7.78$, $p < .007$, and an interaction of clothing, exercise, and drug, $F(1, 51) = 4.11$, $p < .048$. For Correct Per Minute, there was an effect of clothing, $F(1, 51) = 32.10$, $p < .000001$. Participants wearing CPC produced more lapses, were less accurate, and worked at a slower rate, with effect sizes of 0.98, −0.70, and −1.45, respectively.

Because of space limitations, interactions are described but not graphically depicted; they are presented elsewhere (D. Williams et al., 1995). There was an interaction of clothing, exercise, and drug correct on response reaction time. In the utility clothing condition, taking diphenhydramine increased reaction time for exercising participants and decreased reaction time for sedentary participants, whereas participants taking placebo showed decreased reaction time in the exercise group. This pattern of results was reversed for participants wearing CPC.

There was also an interaction of clothing, exercise, and drug on lapses. For participants wearing utility clothing, there was a small increase in lapsing caused by exercising or taking diphenhydramine. However, for participants wearing CPC, exercising participants lapsed less frequently when they took diphenhydramine in comparison with participants taking placebo, whereas sedentary participants lapsed more frequently when they took diphenhydramine.

There was an interaction of clothing, exercise, and drug on accuracy. For participants wearing utility clothing, exercising participants taking diphenhydramine were more accurate than were those who took a placebo, and sedentary participants were less accurate. For participants wearing CPC, exercising participants taking diphenhydramine were less accurate than were those taking a placebo. Sedentary participants showed no effect of drug condition on accuracy.

Discussion. Wearing CPC might produce performance decrements for two different reasons. First, performance decrements might result from cognitive impairments due to the psychological distress produced by wearing CPC. Wearing this clothing requires the user to force air through the respirator and to deal with possible claustrophobic feelings. Furthermore, the impermeability of the suit frequently results in uncomfortable air temperature and humidity inside the suit and increased subjective temperature. Coping with the psychological stress produced by wearing this clothing may lead to decreased cognitive performance. Second, performance decrements might be caused by physical limitations produced by wearing CPC rather than by cognitive impairment. These decrements might be caused either by the restricted visual range produced by the protective facial mask or by clumsiness produced by wearing heavy gloves while trying to make a single keystroke on the computer keyboard and could occur even if the participant were cognitively unimpaired.

The performance problems caused by the mask and gloves are operationally realistic for some situations. However, it is important to separate the relative contributions of psychological and physical problems because these problems allow different solutions. One way to separate the contributions of each factor is to estimate the size of the performance decrement produced by the physical constraints of the clothing. If the performance decrement is well beyond what would be expected from the physical problems, then a cognitive decrement can be inferred.

For example, the visual limitations produced by the mask could have affected cognitive performance. A study of the area of binocular vision for the M17A1 mask (McAlister, Buckingham, & Wingert, 1993) showed that a soldier wearing this mask would have an unrestricted visual field of only a 20° angle. Assuming a distance from the screen was 12 to 16 in. (30–41 cm), the participant would be able to see the information presented without making head or eye movements for all but the Manikin and Matrix-2 tests, which require a larger field of vision than the other tests. Thus, the visual characteristics of the mask probably did not affect performance for the majority of the tests.

Also, the clumsiness caused by wearing gloves might have affected reaction time, accuracy, and rate. This could interfere with finger flexion and would be expected to increase the reaction times. The average difference between CPC and utility clothing conditions in reaction time for tasks requiring little cognitive processing was 10 msec for Tapping, 20 msec for Wilkinson's Four-Choice, and 30 msec for Simple Reaction Time. Thus, if there were no cognitive effects due to wearing CPC, we would expect the difference due to wearing gloves to average 20 msec. When the difference in reaction times between participants wearing CPC and utility uniforms is much larger than that, it probably reflects genuine cognitive impairment.

The extent of the decrease in accuracy caused by the gloves can be estimated from the data for extraneous responses. For each task, only a few of the keys on the keyboard were acceptable response keys. Pressing a nonresponse key was recorded and triggered an auditory warning. Analysis of these extraneous responses for Choice Reaction Time, Simple Reaction Time, Tapping, and Wilkinson's Four-Choice showed that the average difference in the number of these responses between participants wearing CPC and utility clothing was less than 1%. This suggests that the clumsiness produced by wearing gloves had a minimal effect on the accuracy of the response unless the difference between the two groups was only a few percentage points. Of these tests, the only one that may have been substantially influenced by wearing gloves was Tapping because the accuracy difference between participants wearing utility uniforms and CPC was only 4%.

Rate of performance also could have been affected by the gloves. For Tapping, in which both accuracy and reaction time may have been affected by the glove, the rate likely was affected. For other tests, the effect of the glove can be estimated using previously obtained estimates of glove effects on accuracy at 1% and reaction time at 20 msec. The effect of the glove on rate, which is the number correct divided by the sum of the reaction times, was approximated by dividing Percent Correct by Correct Response Reaction Time. These estimates suggest that, for Choice Reaction Time and Wilkinson's Four-Choice, wearing gloves had a minimal effect on rate.

However, lapsing cannot be attributed to the gloves. For the three easy reaction time tests—Simple Reaction Time, Tapping, and Wilkinson's Four-Choice—lapses were defined as responses made 440 to 1,200 msec after presentation of the stimulus. A difference in this variable must reflect a cognitive decrement—presumably in the ability to sustain attention.

Wearing CPC resulted in a significant performance decrement on 10 of the 15 combinations of tests and dependent measures. For 6 of the combinations, it is possible some decrements in reaction time, accuracy, and rate occurred because of wearing gloves. However, for each dependent measure, there is at least one unconfounded statistically significant result showing cognitive impairment for participants wearing CPC. The effect sizes of significant results were in the moderate to large range.

Exercise moderately impaired performance on the reaction time tests. It increased reaction time for Simple Reaction Time, increased lapsing for both Simple Reaction Time and Tapping, and decreased accuracy for the Tapping. Diphenhydramine did not appear to affect the reaction time tests.

When the effect sizes for the results of the reaction time tests are examined without regard to statistical significance, the unconfounded results across the reaction time tests show that wearing CPC moderately impaired performance for reaction time, lapsing, and accuracy and produced a large decrement in rate. Exercise produced inconsistent effects for reaction time, and it produced small effects that increased lapsing and decreased both accuracy and rate. Diphenhydramine produced small effects, which increased lapsing and decreased accuracy. The effect size analysis suggests that effects of each stressor across the reaction time tests generally were to degrade performance.

Spatial Tests

Manikin. For Correct Per Minute, there was an effect of clothing, $F(1, 51) = 5.84$, $p < .019$. Participants wearing CPC worked at a slower rate, with an effect size of –0.58. For Correct Response Reaction Time, there was a Clothing × Exercise interaction, $F(1, 51) = 7.84$, $p < .018$. In the utility uniform condition, exercise participants had longer reaction times than participants who were not exercising. In the CPC condition, exercise participants had somewhat shorter reaction times than participants who were not exercising.

Matrix-2. For Correct Response Reaction Time, there was an effect of clothing, $F(1, 53) = 6.83$, $p < .012$. For Percent Lapses, there was an effect of clothing, $F(1, 53) = 7.81$, $p < .007$, and exercise, $F(1, 53) = 11.40$, $p < .001$. For Correct Per Minute, there was an effect of clothing, $F(1, 53) = 12.72$, $p < .0008$, and of drug, $F(1, 53) = 6.20$, $p < .016$. However, the effect of drug on rate must be discounted because the groups differed at baseline. Participants wearing CPC had longer reaction times, more lapses, and worked at a slower rate, with effect sizes of 0.66, 0.58, and –0.78, respectively. Exercise participants had more lapses, with an effect size of 0.78.

Time Wall. This task differed from the other tasks, and a different dependent measure was used. The task was to predict the arrival time of a falling object, which fell at different rates. The dependent measure used was the absolute value of the difference between the expected and actual object arrival time divided by the actual arrival time. There were no significant effects for this measure.

Discussion. Wearing CPC produced several performance decrements, which could be due to the physical limitations of the clothing or could reflect cognitive impairment. Both the Manikin and Matrix-2 tests require a larger field of vision than do the other tests. Given the visual restrictions of the mask, it is difficult to see the entire Manikin display in a single glance. Because this test requires using information presented at the edge of the display, the participants may have had to make eye or head movements to see the required information, which would increase reaction time. Consequently, the difference in reaction time for this test may have resulted from the reduced visual fields of the mask. However, at these distances, it would be possible to see most or all of the Matrix-2 display. Successful performance on this test is less dependent on peripheral information than is the Manikin test. Thus, the difference in reaction time for the Matrix-2 test is unlikely to be caused by the mask.

The increases in reaction time were much larger than those expected from wearing the gloves. For the Manikin test, there was a 240-msec increase; for the Matrix-2 test, there was a 330-msec increase. The change in reaction time for the Manikin test may be due to the restricted visual fields produced by the mask. However, the change in the Matrix-2 test is unlikely to be due to either the mask or gloves and probably reflects cognitive impairment.

Results of the Matrix-2 test suggest that soldiers wearing CPC may lapse more frequently. Because Lapsing is unaffected by the mask and gloves, these lapses reflect cognitive impairment.

Both Manikin and Matrix-2 tests showed moderate decrements in rate for soldiers wearing CPC. The increase in reaction time for the Manikin test may result from the mask, as may the decrement in rate. However, the Matrix-2 rate change likely indicates a cognitive decrement.

Exercise moderately increased lapsing in Matrix-2. Diphenhydramine produced no unconfounded effects.

The effect size analysis across the Manikin and Matrix-2 tests suggests that wearing CPC produced a moderate to large decrement in performance across spatial tests for Correct Response Reaction Time, Percent Lapses, and Correct Per Minute. The effects on Percent Correct could not be determined because of possible confoundings. Exercise produced a small increase in Percent Lapses and a small decrease in Correct Per Minute. Diphenhydramine showed negligible effects.

Memory Tests

Digit Recall. For Percent Lapses, there was a significant effect of exercise, $F(1, 52) = 6.47$, $p < .014$. Exercise participants made more lapses, with an effect size of 0.59.

Single Digit Substitution. For Correct Response Reaction Time and Correct Per Minute, there was an effect of clothing, $F(1, 53) = 4.18$, $p < .046$, and $F(1, 53)$

$= 5.66$, $p < .021$, respectively. Participants wearing CPC had longer reaction times and worked at a slower rate, with effect sizes of 0.59 and –0.57, respectively.

Six-Letter Search. For Percent Correct and Correct Per Minute, there was an effect of clothing, $F(1, 48) = 5.03$, $p < .030$, and $F(1, 48) = 5.89$, $p < .019$, respectively. Participants wearing CPC were less accurate and worked at a slower rate, with effect sizes of –0.53 and –0.67, respectively.

Discussion. With the exception of Digit Recall accuracy, the effect of the clothing condition in reaction time and accuracy was larger than the effect of wearing gloves. The effect of wearing CPC on memory test performance was significant both for Single Digit Substitution, in which there was an increase in reaction time and a decrease in rate, and for Six-Letter Search, in which there was a decrease in accuracy and a decrease in rate. Consequently, these performance decrements indicate a cognitive impairment.

Exercise increased lapsing on the Digit Recall test. However, diphenhydramine produced no effect.

The effect sizes analysis across memory tests suggests that wearing CPC produced small to moderate memory performance decrements. Exercise produced small decrements in reaction time, accuracy, and rate. Diphenhydramine effects on memory performance were negligible.

Reasoning Tests

Serial Addition/Subtraction. For Correct Response Reaction Time, Percent Lapses, Percent Correct, and Correct Per Minute, there was an effect of clothing, $F(1, 53) = 4.07$, $p < .049$; $F(1, 53) = 7.20$, $p < .01$; $F(1, 53) = 5.84$, $p < .019$; and $F(1, 53) = 16.05$, $p < .0002$, respectively. Participants wearing CPC had longer reaction times, made more lapses, were less accurate, and worked at a slower rate, with effect sizes of 0.59, 0.66, –0.56, and –1.04, respectively.

Encode/Decode. For Correct Response Reaction Time, there was an effect of clothing, $F(1, 49) = 5.62$, $p < .022$. For Percent Lapses, there was an effect of exercise, $F(1, 53) = 4.02$, $p < .05$. For Correct Per Minute, there was an effect of clothing, $F(1, 53) = 5.59$, $p < .022$. Participants wearing CPC had longer reaction times and worked at a slower rate, with effect sizes of 0.68 and –0.63, respectively. Exercise participants made more lapses, with an effect size of 0.49.

Logical Reasoning. For Percent Lapses and Correct Per Minute, there was an effect of exercise, $F(1, 46) = 5.18$, $p < .028$, and $F(1, 46) = 4.18$, $p < .047$, respectively. Exercise participants were more likely to lapse and worked at a slower rate, with effect sizes of 0.62 and –0.60, respectively.

Discussion. Because the magnitude of the increases in reaction time and the decreases in accuracy are far larger than could be caused by only wearing gloves, they probably reflect a cognitive decrement. The effects of wearing CPC decreased performance for all measures of performance of Serial Addition/Subtraction and decreased performance on Correct Response Reaction Time and Correct Per Minute for Encode/Decode.

Results also showed that exercise increased lapsing on both Encode/Decode and Logical Reasoning and moderately decreased the rate for Logical Reasoning. There were no main effects of diphenhydramine.

The effect size analysis across reasoning tests suggests that wearing CPC produced a small decrease in Percent Correct and a large increase in Correct Response Reaction Time and Correct Per Minute. Activity produced a moderate increase in Percent Lapses and a decrease in Correct Per Minute. Diphenhydramine produced a small improvement in Correct Response Reaction Time.

GENERAL DISCUSSION

Considering effects that are uncontaminated by physical problems produced by wearing the mask or the gloves, wearing CPC produced at least one statistically significant cognitive deficit in each category of test for the dependent measures of reaction time and rate. Additionally, there was evidence that lapsing and accuracy were affected for three test categories. The generality of the cognitive deficit is supported by the effect size analysis. When the effect sizes are averaged for all unconfounded results across the four categories of tests, the average effect of wearing CPC was a small increase in lapsing, a medium increase in reaction time, a medium decrease in accuracy, and a large decrease in rate.

The statistically significant effects of exercise were always to decrease performance—chiefly through moderately increasing the number of lapses. The effect of exercise depends on how strenuous the exercise is and how much exercise has been accomplished when the participants were tested (Tomporowski & Ellis, 1986). Because the exercise participants carried a heavy backpack for 18 to 24 miles (29–39 km) at the time our data were collected, they likely were past the invigorating part of the exercise. Their physical fatigue manifested in lapses on half of the tests. This has been observed before in sleep-deprived participants in response to more moderate levels of exercise (Angus, Heslegrave, & Myles, 1985). However, this variable is rarely used in exercise research. There also was evidence that exercise either increased reaction time or decreased accuracy or rate on three different tests. There was no significant performance improvement on any test. The effect size analysis showed a small average effect size increasing lapsing and decreasing accuracy and rate.

There were no unconfounded statistically significant main effects of taking diphenhydramine. Although there were individual effects that approached significance, the effect size analysis across the four categories of tests provided no evidence for a general effect.

The lack of general impairment due to diphenhydramine was somewhat surprising given the drug's reported effects of producing sedation and cognitive impairment. However, as previously mentioned, the majority of research on this drug investigated the effects of a single dose, rather than of multiple doses. Multiple dosing may have led to the development of tolerance. Previous research found no cognitive performance impairment by the 3rd dosing day (Schweitzer et al., 1994). The research presented here suggests that tolerance develops by the 2nd day of dosing. Data from the first 6 hr of data collection shows that average effect sizes for the first dosing interval were in the small range, but some effects were statistically significant. The attenuation of these already small effects may account for the relative lack of impairment seen in the data from the last 8 hr of the study.

Given diphenhydramine's relatively long half-life of 8.5 hr, the dosing interval, and number of doses, it is likely the participants' blood plasma levels approached steady state by the time of testing. If blood plasma is important in determining side effect severity (Carruthers, Shoeman, Hignite, & Azarnoff, 1978; Licko et al., 1986), tests from different batteries would be equivalently affected. However, if the participants' blood plasma levels fluctuated substantially, then the cognitive performance effects of diphenhydramine might only affect tests administered 2 to 4 hr postdosing, at the time of peak blood plasma. Because the sixth dose was given at noon during Block 4, participants would have achieved peak plasma levels between 1400 hr and 1600 hr, during administration of tests from Battery 2. Examination of the average effect sizes from these tests shows no further impairment during this battery, making it unlikely that cognitive performance decrements were produced by diphenhydramine for a limited interval, which was obscured by examination of effects from all three batteries of tests.

The stressors produced few interactions, and those interactions did not always suggest a synergistic effect of the stressors on cognitive performance. It might have been expected that the physical fatigue produced by prolonged moderate exercise combined with the sedative effects of diphenhydramine and the stress of being in CPC would be more than additive for our sleep-deprived participants. However, the dearth of interactions suggests the combined effects of these stressors can be estimated using an additive model. A lack of interactions among similar factors was also reported by Arad et al. (1992).

The conclusion that wearing CPC produces cognitive decrements not due to the clumsiness of the gloves or the visual limitations of the mask is a new interpretation. As mentioned previously, several researchers have reported a decrement in cognitive performance produced by this clothing (Englund et al., 1987; Englund et al., 1988; Kelly, Englund, et al., 1988; Kobrick & Sleeper, 1986; Rauch et al., 1986). However, these researchers interpreted these decrements as resulting from physical limitations produced by the clothing. The results presented here suggest that, even when the extent of these physical limitations is taken into account, wearing this clothing produces a moderate cognitive decrement in Marines who are experienced in wearing this clothing.

The degradations in cognitive test performance produced by wearing CPC mirror decrements reported for simulations of military tasks. Johnson, McMenemy, and Dauphinee (1990) showed that wearing CPC decreased accuracy by 15% on shooting pop-up targets presented by a Weaponeer marksmanship simulator. Hamilton, Folds, and Simmons (1982) found that helicopter pilots wearing CPC had performance decrements with effect sizes of 0.62 for maintaining heading and 0.46 for holding a constant airspeed. These errors are in the range of the errors seen in the cognitive test performance.

Similarly, the cognitive decrements produced by exercise mirror the military performance decrements seen following a 20-km road march carrying a 45-kg pack. Knapik et al. (1990) found decrements in marksmanship hits and distance from the target, with effect sizes of –0.72 and 0.68, respectively.

This report makes several contributions. First, because of the large sample size and the number of cognitive tests used, the data are more reliable and more representative of different cognitive abilities than previous studies of CPC. Second, this is the first report of dependent measures using empirically derived, sensitive measures that may be related to operational performance (D. Williams, 1995). Third, evidence is provided that the performance decrement caused by wearing CPC is not due solely to the physical effects of the clothing. Fourth, this is the first report of an increase in lapses in responding due to wearing CPC. Fifth, a general cognitive impairment caused by prolonged moderate exercise in sleep-deprived participants is demonstrated. Finally, this report shows that the cognitive deficit initially produced by ingestion of diphenhydramine has resolved after 1 day of repeated dosing.

Operationally, although decrements in accuracy, reaction time, and efficiency are important, the inability of soldiers wearing CPC or who have engaged in prolonged moderate exercise to sustain attention to a task may well be more important. These performance lapses produce a qualitative change in performance that could adversely affect performance on military tasks.

The results of this study suggest that sleep-deprived soldiers wearing CPC will take longer to do the task, even when lapses are not counted as part of task performance. They will have trouble maintaining attention to the task, and their performance will be less accurate. These cognitive decrements will result in less efficient cognitive processing. Sleep-deprived soldiers who perform prolonged physical work of moderate intensity will have trouble maintaining attention to the task, and they will be less accurate and less efficient. The results presented here suggest that, if sleep-deprived soldiers' jobs are near the limit of their cognitive abilities, and if they must wear CPC or engage in prolonged, moderate exercise, they may be unable to perform their job satisfactorily.

These results may also apply to other situations that require either wearing protective clothing or strenuous exercise. For example, firefighters and personnel involved in chemical spill cleanup may be similarly affected. If their work is intellectually demanding and requires them to stay in CPC for several hours, or if they are fatigued from exercise, their job performance may be compromised.

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REFERENCES

Angus, R. G., Heslegrave, R. J., & Myles, W. S. (1985). Effects of prolonged sleep deprivation, with and without chronic physical exercise, on mood and performance. *Psychophysiology, 22*, 276–282.

Arad, M., Varssano, D., Moran, D., Arnon, R., Vazina, A., & Epstein, Y. (1992). Effects of heat-exercise stress, NBC clothing, and pyridostigmine treatment on psychomotor and subjective measures of performance. *Military Medicine, 157*, 210–214.

Babe, K. S., & Serafin, W. E. (1996). Histamine, bradykinin, and their antagonists. In J. G. Hardman & L. E. Limbird (Eds.), *Goodman and Gilman's the pharmacological basis of therapeutics* (9th ed., pp. 581–600). New York: McGraw-Hill.

Baugh, R., & Calvert, R. T. (1977). Effect of diphenhydramine and ethanol on histamine skin response and mental performance. *European Journal of Clinical Pharmacology, 12*, 201–204.

Benet, L. Z., Oie, S., & Schwartz, J. B. (1996). Design and optimization of dosage regimens: Pharmacokinetic data. In J. G. Hardman & L. E. Limbird (Eds.), *Goodman and Gilman's the pharmacological basis of therapeutics* (9th ed., pp. 1707–1792). New York: McGraw-Hill.

Bills, A. G. (1931). Blocking: A new principle in mental fatigue. *American Journal of Psychology, 43,* 230–245.

Bills, A. G. (1958). Studying motor functions and efficiency. In T. G. Andrews (Ed.), *Methods of psychology* (pp. 459–497). New York: Wiley.

Bjener, B. (1949). Alpha depression and lowered pulse rate during delayed actions in a serial reaction test. *Acta Physiologica Scandinavica, 19,* 93.

Brooks, F. R., Xenakis, S. N., Ebner, D. G., & Balson, P. M. (1983). Psychological reactions during chemical warfare training. *Military Medicine, 148,* 232–235.

Carruthers, S. G., Shoeman, D. W., Hignite, C. E., & Azarnoff, D. L. (1978). Correlations between plasma diphenhydramine level and their sedative and antihistamine effects. *Clinical Pharmacological Therapy, 23,* 375–382.

Carter, B. J., & Cammermeyer, M. (1985). Biopsychological responses of medical unit personnel wearing chemical defense ensemble in a simulated chemical warfare environment. *Military Medicine, 150,* 239–249.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Craig, F. N., Blevins, W. V., & Cummings, E. G. (1970). Exhausting work limited by external resistance and inhalation of carbon dioxide. *Journal of Applied Physiology, 29,* 847–851.

Englund, C. E., Kelly, T. L., Ryman, D. H., Yeager, J. E., Sucec, A. A., & Smith, D. A. (1987). Cognitive performance during 12 hours of continuous work in MOPP IV. In *Proceedings of the Sixth Medical Chemical Defense Bioscience Review* (pp. 665–668). Aberdeen Proving Ground, MD: U.S. Army Medical Research Institute of Chemical Defense.

Englund, C. E., Sucec, A. A., Yeager, J. E., Ryman, D. H., & Sinclair, M. (1988, August). *Heavy physical work in protective ensemble effects on cognitive performance.* Paper presented at the meeting of the American Psychological Association, Atlanta, GA.

Fine, B. J. (1988). *The effect of heat and chemical protective clothing on the ability of a group of female soldiers to sustain performance of military cognitive tasks* (Rep. No. T7–88). Natick, MA: U.S. Army Research Institute of Environmental Medicine. (DTIC No. AD–A192 596)

Gengo, F. M., Gabos, C., & Mechtler, L. (1990). Quantitative effects of cetirizine and diphenhydramine on mental performance using an automobile driving simulator. *Annals of Allergy, 64,* 520–526.

Gilman, A. G., Rall, T. W., Nies, A. S., Taylor, P. (Eds.). (1990). *Goodman and Gilman's the pharmacological basis of therapeutics* (8th ed.). New York: Pergamon.

Glass, G. V., McGaw, B., & Smith, M. L. (1981). *Meta-analysis in social research.* Beverly Hills, CA: Sage.

Glenn, S. W., & Parsons, O. A. (1990). The role of time in neuropsychological performance: Investigation and application in an alcoholic population. *The Clinical Neuropsychologist, 4,* 344–354.

Gliner, J. A., Matsen-Twisdale, J. A., Horvath, S. M., & Maron, M. B. (1979). Visual evoked potentials and signal detection following a marathon race. *Medicine and Science in Sports, 11,* 155–159.

Hamilton, B. E., Folds, D., & Simmons, R. R. (1982). *Performance impact of current United States and United Kingdom aircrew chemical defense ensembles* (Rep. No. 82–9). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. (DTIC No. AD–A121 502)

Hamilton, B. E., Simmons, R. R., & Kimball, K. A. (1983). *Psychological effects of chemical defense ensemble imposed heat stress on Army aviators* (Rep. No. 83–6). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. (DTIC No. AD–A121 956)

Hamilton, B. E., & Zapata, L. (1983). *Psychological measurements during the wear of the U.S. aircrew chemical defense ensemble* (Rep. No. 83–7). Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. (DTIC No. AD–A125 619)

Hays, W. L. (1973). *Statistics for the social sciences* (2nd ed.). New York: Holt, Rinehart & Winston.

Hunter, J. E., Schmidt, F. L., & Jackson, G. B. (1982). *Meta-analysis.* Beverly Hills, CA: Sage.

Johnson, R. F., McMenemy, D. J., & Dauphinee, D. T. (1990). Rifle marksmanship with three types of combat clothing. *Proceedings of the Human Factors Society, 34,* 1529–1532.

Kelly, T. L., Englund, C. E., Ryman, D. H., Yeager, J. E., & Sucec, A. A. (1988). *The effects of 12 hours of MOPP IV gear on cognitive performance under non-exercise conditions* (Rep. No. 88–6). San Diego, CA: Naval Health Research Center. (DTIC No. AD–A192 527)

Kelly, T. L., Ryman, D. H., Sucec, A. A., Yeager, J. E., Englund, C. E., & Smith, D. A. (1988). *The effects of the M17A2 gas mask on reaction times and accuracy in males and females under non-exercise conditions* (Rep. No. 88–5). San Diego, CA: Naval Health Research Center. (DTIC No. AD–A192 528)

Kelly, T. L., Yeager, J. E., Sucec, A. A., Ryman, D., Englund, C. E., & Smith, D. A. (1987). Effects of the M17A2 gas mask on resting spirometry and reaction time-accuracy measures under sedentary conditions. In *Proceedings of the Sixth Medical Chemical Defense Bioscience Review* (pp. 673–676). Aberdeen Proving Ground, MD: U.S. Army Medical Research Institute of Chemical Defense.

Knapik, J., Staab, J., Bahrke, M., Reynolds, K., Vogel, J., & O'Connor, J. (1990). *Soldier performance and mood states following a strenuous road march* (Rep. No. T20–90). Natick, MA: U.S. Army Research Institute of Environmental Medicine. (DTIC No. AD–A217 895)

Kobrick, J. L., & Sleeper, L. A. (1986). Effect of wearing chemical protective clothing in the heat on signal detection over the visual field. *Aviation, Space, and Environmental Medicine, 57,* 144–148.

Licko, V., Thompson, T., & Barnett, G. (1986). Asynchronies of diphenhydramine plasma—Performance relationships. *Pharmacology Biochemistry & Behavior, 25,* 365–370.

Linnoila, M. (1973). Effects of antihistamines, chlormezanone, and alcohol on psychomotor skills related to driving. *European Journal of Clinical Pharmacology, 5,* 247–254.

Loftus, G. R. (1991). On the tyranny of hypothesis testing in the social sciences. *Contemporary Psychology, 36,* 102–105.

Loftus, G. R. (1993). A picture is worth 1000 *p* values: On the irrelevance of hypothesis testing in the microcomputer age. *Behavior Research Methods, Instruments, & Computers, 25,* 250–256.

Lybrand, W., Andrews, T., & Ross, S. (1954). Systematic fatigue and perceptual organization. *American Journal of Psychology, 67,* 704–707.

McAlister, W. H., Buckingham, R. S., & Wingert, T. A. (1993). A comparison of the visual field restrictions with the M17 series protective mask and the MCU-2/P chemical–biological mask. *Military Medicine, 158,* 266–269.

Morgan, W. P. (1983). Psychological problems associated with the wearing of industrial respirators: A review. *American Industrial Hygiene Association Journal, 44,* 671–676.

Morgan, W. P., & Raven, P. B. (1985). Prediction of distress for individuals wearing industrial respirators. *American Industrial Hygiene Association Journal, 46,* 363–368.

Patrick, G. T., & Gilbert, J. A. (1896). On the effects of loss of sleep. *Psychological Review, 3,* 469–483.

Pishkin, V., Sengel, R. A., Lovallo, W. R., & Shurley, J. T. (1983). Cognitive and psychomotor evaluation of clemastine-fumarate, diphenhydramine HCL and hydroxyzine HCL: Double-blind study. *Current Therapeutic Research, 33,* 230–237.

Rauch, T. M., Witt, C., Banderet, L. E., Tauson, R., & Golden, M. (1986). *The effects of wearing chemical protective clothing on cognitive problem solving* (Rep. No. T18–86). Natick, MA: U.S. Army Research Institute of Environmental Medicine. (DTIC No. AD–A176 206)

Raven, P. B., Dodson, A. T., & Davis, T. O. (1979). The physiological consequences of wearing industrial respirators: A review. *American Industrial Hygiene Journal, 40,* 517–534.

Rice, V. J., & Snyder, H. L. (1993). The effects of Benadryl and Hismanal on psychomotor performance and perceived performance. *Aviation, Space, and Environmental Medicine, 64,* 726–734.

Rickels, K., Morris, R. J., Newman, H., Rosenfeld, H., Schiller, H., & Weinstock, R. (1983). Diphenhydramine in insomniac family practice patients: A double-blind study. *Journal of Clinical Pharmacology, 23,* 235–242.

Roth, T., Roehrs, T., Koshorek, G., Sicklesteel, J., & Zorick, F. (1987). Sedative effects of antihistamines. *Journal of Allergy and Clinical Immunology, 80,* 94–98.

Schmidt, F. L. (1992). What do data really mean? Research findings, meta-analysis, and cumulative knowledge in psychology. *American Psychologist, 47,* 1173–1181.

Schrot, J., Thomas, J. R., & Van Orden, K. (1990). *Human performance following antihistamine administration* (Rep. No. NMRI 90–127). Bethesda, MD: Naval Medical Research Institute. (DTIC No. AD–A233 051)

Schweitzer, P. K., Muehlbach, M. J., & Walsh, J. K. (1994). Sleepiness and performance during three-day administration of cetirizine or diphenhydramine. *Journal of Allergy and Clinical Immunology, 94,* 716–724.

Spioch, F. M., Kobza, R., & Rump, S. (1962). The effects of respirators on the physiological reaction to physical effort. *Acta Physiologica Polonica, 13,* 637–649.

Stemler, F. W., & Craig, F. N (1977). Effects of respiratory equipment on endurance in hard work. *Journal of Applied Physiology: Respiratory Environmental Exercise Physiology, 42,* 28–32.

Thorne, D., Genser, S., Sing, H., & Hegge, F. (1983). Plumbing human performance limits during 72 hours of high task load. In S. E. Forshaw (Ed.), *Proceedings of the 24th DRG Seminar on the Human as a Limiting Element in Military Systems* (NATO-DRG Rep. No. DS–A–DR(83) 170, Vol. 1, pp. 17–40). Toronto, Canada: NATO Defense Research Group.

Thorne, D., Genser, S., Sing, H., & Hegge, F. (1985). The Walter Reed performance assessment battery. *Neurobehavioral Toxicology and Teratology, 7,* 415–418.

Tomporowski, P. D., & Ellis, N. R. (1986). Effects of exercise on cognitive processes: A review. *Psychological Bulletin, 99,* 338–346.

Tomporowski, P. D., Ellis, R. N., & Stephens, R. (1987). The immediate effects of aerobic exercise on free-recall memory. *Ergonomics, 30,* 121–129.

Warren, N., & Clarke, B. (1937). Blocking in mental and motor tasks during a 65 hour vigil. *Journal of Experimental Psychology, 62,* 263–271.

Williams, D. (1995). *The relative sensitivity of cognitive tests and dependent measures determined using vote-counting* (Rep. No. 95–44). San Diego, CA: Naval Health Research Center.

Williams, D., Englund, C. E., Sucec, A. A., & Overson, M. D. (1995). *Effects of chemical protective clothing, exercise, and diphenhydramine on cognitive performance during sleep deprivation* (Rep. No. 95–8). San Diego, CA: Naval Health Research Center.

Williams, H. L., Lubin, A., & Goodnow, J. J. (1959). Impaired performance with acute sleep loss. *Psychological Monographs, 73*(14, No. 484), 1–26.

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13. ABSTRACT *(Maximum 200 words)*

The cognitive performance effects of some stressors experienced in military training and combat were determined in a field experiment. The effects of wearing chemical protective clothing (CPC) (MOPP IV), walking 30-45 km while carrying a heavy backpack, and taking 50-mg oral doses every 6 hr of diphenhydramine, an antihistamine, were investigated on 72 Marines during a 36-hr sleep deprivation double-blind, placebo-controlled experiment. We administered tests that measured reaction time, spatial ability, memory, and logical reasoning. The results suggest that wearing CPC for an 11-hr period or prolonged engagement in moderate exercise produces general cognitive impairment in sleep-deprived subjects. However, after repeated dosing, taking diphenhydramine has little cognitive effect. These results suggest that if a job is near the limit of a person's cognitive abilities, performance may suffer if the person is sleep deprived and required to wear CPC or engage in prolonged, moderate exercise.

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